U.S. Department of the Interior
U.S. Geological Survey

Updated Techniques for Estimating Monthly Streamflow-Duration Characteristics at Ungaged and Partial-Record Sites in Central Nevada

Open-File Report 02-168

Prepared in cooperation with the
U.S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE,
TOIYABE NATIONAL FOREST

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2002	**N/A**	**-**

4. TITLE AND SUBTITLE
Updated Techniques for Estimating Monthly Streamflow-Duration Characteristics at Ungaged and Partial-Record Sites in Central Nevada

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Department of the Interior U.S. Geological Survey 1849 C. Street, NW Washington, DC 20240

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**20**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Cover photograph: Westward view of Toquima Range from east side of Monitor Valley in September 1996. Four streams discussed in this report drain eastward from the Toquima Range (see fig. 1). Photograph by John Potyondy, U.S. Forest Service.

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Carson City, Nevada
2002

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Multiply	By	To obtain
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called “Sea-Level Datum of 1929”), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

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Updated Techniques for Estimating Monthly Streamflow-Duration Characteristics at Ungaged and Partial-Record Sites in Central Nevada

By Glen W. Hess

ABSTRACT

Techniques for estimating monthly streamflow-duration characteristics at ungaged and partial-record sites in central Nevada have been updated. These techniques were developed using streamflow records at six continuous-record sites, basin physical and climatic characteristics, and concurrent streamflow measurements at four partial-record sites.

Two methods, the basin-characteristic method and the concurrent-measurement method, were developed to provide estimating techniques for selected streamflow characteristics at ungaged and partial-record sites in central Nevada. In the first method, logarithmic-regression analyses were used to relate monthly mean streamflows (from all months and by month) from continuous-record gaging sites of various percent exceedence levels or monthly mean streamflows (by month) to selected basin physical and climatic variables at ungaged sites. Analyses indicate that the total drainage area and percent of drainage area at altitudes greater than 10,000 feet are the most significant variables. For the equations developed from all months of monthly mean streamflow, the coefficient of determination averaged 0.84 and the standard error of estimate of the relations for the ungaged sites averaged 72 percent. For the equations derived from monthly means by month, the coefficient of determination averaged 0.72 and the standard error of estimate of the relations averaged 78 percent. If standard errors are compared, the relations developed in this study appear generally to be less accurate than those developed in a previous study. However, the new relations are based on additional data and the slight increase in error may be due to the wider range of streamflow for a longer period of record, 1995–2000.

In the second method, streamflow measurements at partial-record sites were correlated with concurrent streamflows at nearby gaged sites by the use of linear-regression techniques. Statistical measures of results using the second method typically indicated greater accuracy than for the first method. However, to make estimates for individual months, the concurrent-measurement method requires several years additional streamflow data at more partial-record sites. Thus, exceedence values for individual months are not yet available due to the low number of concurrent-streamflow-measurement data available. Reliability, limitations, and applications of both estimating methods are described herein.

INTRODUCTION

Effective management of surface-water resources requires accurate information on the magnitude and variability of streamflow. Monthly mean flow, a statistical measure of these important properties, is of particular interest to fish and wildlife managers, water rights administrators, and other land- and water-use planners.

In central Nevada, where precipitation is light and related streamflow is intermittent, flow data are collected non-continuously and at widely spaced sites. As a result, calculation of accurate monthly streamflow-duration characteristics for streams in the area requires methods for regionalizing data from ungaged and partial-record sites.

Beginning in 1996, a need for this type of information for upland streams in central Nevada was identified and an investigation was undertaken by the U.S. Geological Survey (USGS) in cooperation with the U.S. Department of Agriculture, Forest Service (USFS), Toiyabe National Forest. An initial study was done by Hess and Bohman (1996) to determine methods for estimating monthly streamflow. Since then, an additional 4 years (1997–2000) of streamflow data have been collected. This report is a summary of the additional data collected and methods for estimating monthly streamflow-duration characteristics that have been updated with the additional data.

Purpose and Scope

This report (1) describes the data used to estimate streamflow, (2) describes two techniques for estimating monthly streamflow-duration characteristics at ungaged and partial-record sites in central Nevada, (3) discusses the reliability and limitations of those techniques, and (4) discusses applications of the estimating methods.

Previous Investigations

Methods of regionalizing selected streamflow characteristics and evaluating the reliability of each under various hydrologic conditions were described in Riggs (1972, 1973). In addition, Riggs (1973) provided examples of regionalizing streamflow characteristics for high and low flows.

Moore (1968) developed two methods for estimating mean annual runoff in ungaged semiarid areas that are applicable to either perennial or ephemeral streams. The first method, based on streamflow records, relates annual runoff to altitude for a region. The second method relates annual runoff to channel width and depth.

Maurer (1986) developed regression equations for estimating streamflow at seven tributaries of the Carson River in Carson Valley based on data from an index gaging station and concurrent-streamflow measurements (U.S. Geological Survey, 1981–83). Later, Hess (1999) updated the equations developed by Maurer (1986) with additional concurrent-measurement data expanding the database by six additional tributaries in the Carson Valley area.

Parrett and Cartier (1990) developed three methods for estimating monthly mean streamflow and various points on the daily mean streamflow-duration curve for each month, which are applicable to western Montana basins. The first method is based on multiple regression equations relating the monthly streamflow characteristics to various basin physical and climatic variables. The second method is based on regression equations relating the monthly streamflow characteristics to channel width. The third method requires monthly streamflow measurements made concurrently at the partial-record sites of interest with nearby measurements made at hydrologically similar gaged sites. This concurrent-measurement method is more reliable than the other methods for all months and nearly all monthly streamflow characteristics.

Myers and Swanson (1996) extended the record of monthly streamflows at a gaging station in northwestern Nevada using multiple-regression techniques. The purpose of these estimates was to aid in the comparison of different range management plans in the recovery of two overgrazed riparian habitats.

Hess and Bohman (1996) developed techniques for estimating monthly mean streamflow at gaged sites and monthly streamflow-duration characteristics at ungaged sites in central Nevada. Streamflow records at six gaged sites for the period 1951–95 and basin physical and climatic characteristics were used to determine equations for each month and for the entire period of record. Analyses indicated that the drainage area and percent of drainage area at altitudes greater than 10,000 ft were the most significant variables in those equations. Reliability and limitations of the estimating methods were described.

Using a similar analysis, Hess (2002) developed techniques for estimating monthly streamflow-duration characteristics for tributary inflows to the Middle Humboldt River. Relating drainage area and latitude to gaging station streamflow records and regression equations were developed. These equations were based on streamflow records at 33 gaging stations in northern Nevada for water years 1944–99 and were applicable

only to that area. A water year is the 12-month period October 1 through September 30. Thus, the year ending September 30, 1999, is called the "1999 water year."

Description of Study Area

The study area is in northern Nye County, and parts of southern Lander and Eureka Counties, Nev. Termed "central Nevada" for the purposes of this report, the study area is composed largely of north-south trending mountain ranges separated by long narrow valleys (fig. 1). The study area includes basins above about 6,000 ft in the Shoshone Mountains, and the Toiyabe, Toquima, Monitor, and Hot Creek Ranges. Altitudes for the basins studied in this investigation ranged from about 6,400 to 12,000 ft above sea level. U.S. Highway 50 bounds the study on the north; the Shoshone Mountains and Hot Creek Range form the western and eastern boundaries of the study area, respectively. The study area generally is rugged and sparsely forested. Methods discussed in this report are not applicable to the flatter valley floors, which are mostly open range but may be used for grazing or limited agriculture.

Annual precipitation in the study area varies widely primarily because of the wide range in altitudes and resultant orographic effects. Annual precipitation values can vary from 30 in. at higher altitudes to 6 in. or less in the valley floors. Annual runoff generally mimics the precipitation with greater quantities occurring at higher altitudes than those at lower altitudes. Streamflows vary greatly on a seasonal basis; the bulk of the annual runoff occurs as snowmelt in spring (April, May, and June). In late fall and winter streamflows generally are smaller than in spring and are provided almost entirely by ground-water discharge.

Streamflow Data Used

Monthly streamflow statistics were computed from daily data at six streamflow-gaging stations within the study area (fig. 1, table 1). Continuous streamflow data for central Nevada for water years 1951–2000 were used in the analyses. Each continuous-record station had to have at least 5 years of record through water year 2000, to be included in the study, although some stations did not have a complete record for all months. The period of record for all stations did not necessarily overlap. Data from streamflow-gaging stations were excluded from the analyses if flows were substantially regulated or if flows were affected substantially by large diversions. Ephemeral streams also were not included in the analyses. The monthly mean streamflows computed for each station were published in Hendricks (1963), USGS (1962–2000, published annually), and McKinley and Oliver (1994, 1995).

Partial-record data were collected by the USGS in cooperation with the USFS from April through October for water years 1997–2000 at four basins (fig. 1, table 2) within the study area. A series of 19 single streamflow measurements were made at each of the four sites along with concurrent-streamflow measurements at nearby hydrologically similar continuous-record sites. These measurement data were published in USGS (1997–2000, published annually).

METHODS FOR ESTIMATING MONTHLY STREAMFLOW-DURATION CHARACTERISTICS AT UNGAGED AND PARTIAL-RECORD SITES

Equations from regression analysis cannot be used *directly* to estimate unique historical streamflows at ungaged sites. However, certain statistical streamflow-duration characteristics can be estimated for ungaged sites by extending streamflow records from gaged sites to sites with selected similar basin physical and climatic characteristics. Alternatively, concurrent-streamflow measurements at partial-record sites and nearby continuous-record sites (with known duration characteristics) can be used to estimate streamflow-duration characteristics at the partial-record site. These methods are used by Parrett and Cartier (1990) and by Riggs (1972, 1973).

Using the basin-characteristics method and a statistical analysis of available monthly data, duration curves of monthly mean streamflows were constructed for each of the six gaged sites. Monthly mean streamflow is defined as the average daily streamflow for any given month averaged over the month. At each gaged site, monthly mean streamflows with exceedence values of 1, 5, 10, 25, 50, 75, 90, 95, and 99 percent (table 3) were regressed against certain basin physical and climatic characteristics (table 4) for all months. In addition, streamflows with exceedence values of 5, 25, 50, 75, and 95 percent were regressed against certain basin physical and climatic characteristics for percent exceedence values for each month of the year.

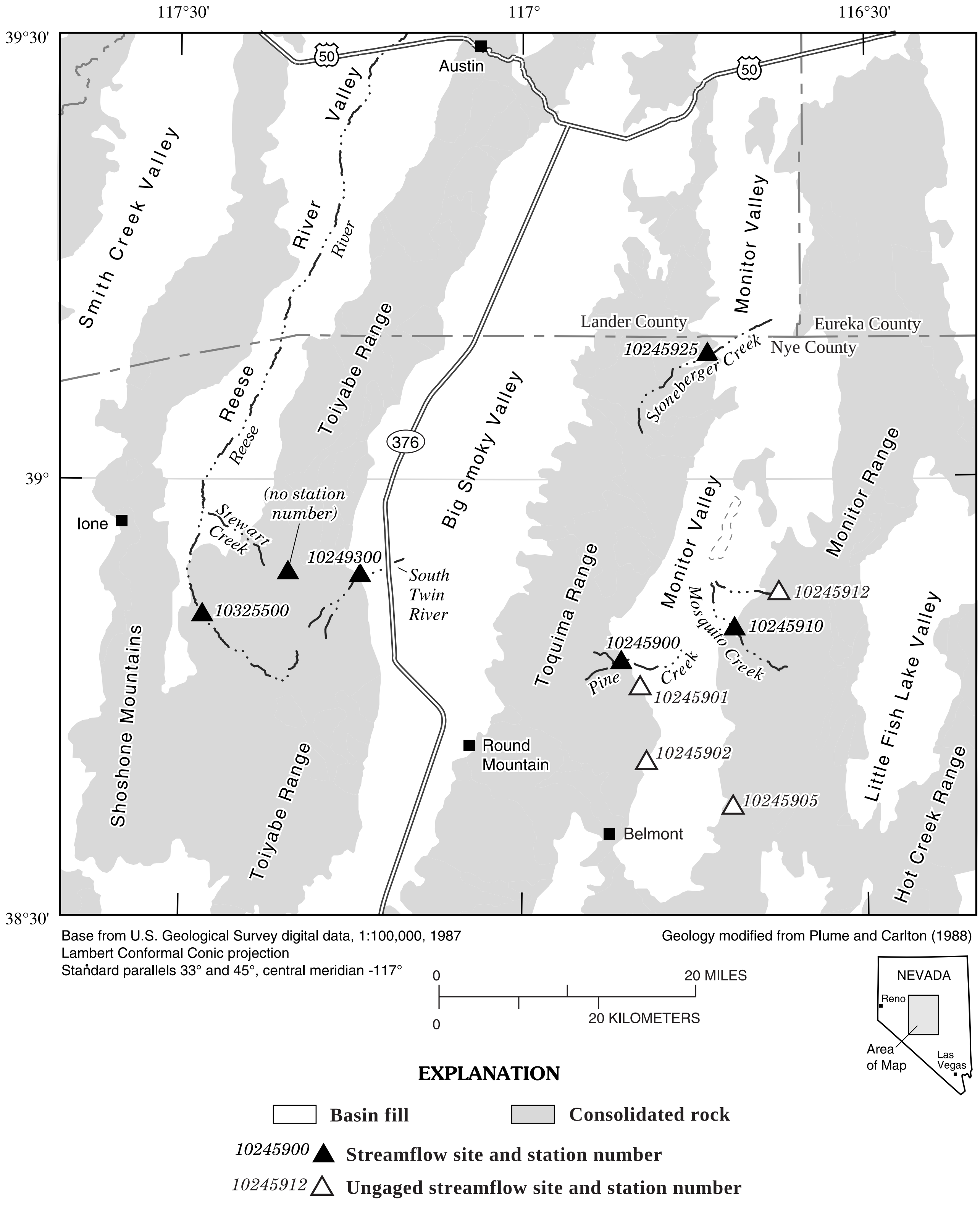

Figure 1. Location of streamflow site and station number in central Nevada.

Table 1. Mean monthly streamflow of drainage basins in central Nevada

[Symbol: —, no assigned station number]

Station number (fig. 1)	Station name	Period of statistics (water year)	Mean monthly streamflow (cubic feet per second)											
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
10245900	Pine Creek near Belmont	1978–2000	2.27	1.85	1.52	1.35	1.26	1.63	3.13	16.6	24.2	7.99	3.62	2.35
10245910	Mosquito Creek near Belmont	1978–2000	.80	.74	.60	.54	.52	.68	1.54	6.44	10.9	3.28	1.25	.80
10245925	Stoneberger Creek near Belmont	1978–1997	.56	.55	.52	.49	.53	.67	1.28	5.15	6.59	2.05	1.05	.66
10249300	South Twin River near Round Mountain	1965–2000	2.47	2.65	2.46	2.38	2.59	4.75	9.23	25.2	19.5	6.37	2.94	2.26
10325500	Reese River near Ione	1951–1980	2.70	2.56	2.50	2.51	3.25	5.75	23.3	48.2	29.9	8.81	3.86	2.69
—	East Stewart Creek near Ione	1987–1991	.20	.17	.15	.11	.08	.09	.18	.69	1.35	.53	.30	.19

Table 2. Mean monthly streamflow determined at concurrent partial-record sites in central Nevada, water years 1997–2000

[Symbol: —, no measurements made during month]

Station number (fig. 1)	Station name	Mean monthly streamflow from concurrent-measurement data (cubic feet per second)											
		Month (number of streamflow measurements)											
		Oct. (2)	Nov. (0)	Dec. (0)	Jan. (0)	Feb. (0)	Mar. (0)	April (2)	May (3)	June (4)	July (3)	Aug. (1)	Sep. (4)
10245901	Andrews Creek near Belmont	0.12	—	—	—	—	—	1.26	1.33	3.68	1.17	0	0.24
10245902	Corcoran Creek near Belmont	.45	—	—	—	—	—	.39	.49	.61	.50	.24	.41
10245905	Barley Creek near Belmont	.79	—	—	—	—	—	8.3	23.7	26.6	3.38	0	1.21
10245912	Morgan Creek near Belmont	.26	—	—	—	—	—	.38	1.61	1.62	.82	.10	.26

Table 3. Monthly streamflow-duration characteristics of streams at continuous-record sites in central Nevada

[Symbol: —, no assigned station number]

Station number	Station name	Monthly streamflow equalled or exceeded for indicated percentage of time (cubic feet per second)								
		1	5	10	25	50	75	90	95	99
10245900	Pine Creek near Belmont	61.0	21.7	16.2	4.43	1.93	1.37	1.10	1.02	0.83
10245910	Mosquito Creek near Belmont	17.3	9.36	4.24	1.71	.78	.49	.33	.27	.16
10245925	Stoneberger Creek near Belmont	24.4	6.33	3.05	1.26	.45	.24	.18	.15	.10
10249300	South Twin River near Round Mountain	57.5	25.5	14.5	6.38	2.90	1.99	1.49	1.25	.92
10325500	Reese River near Ione	139	60.0	33.6	9.56	3.86	2.42	1.53	1.20	.59
—	East Stewart Creek near Ione	2.04	1.22	.87	.38	.20	.12	.08	.07	.05

Table 4. Selected physical and climatic characteristics of selected drainage basins in central Nevada

[Symbol: —, no assigned station number]

Station number	Station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Period of record (water year)	Drainage area (square miles)	Gage altitude (feet above sea level)	Main channel slope (feet per mile)	Mean basin altitude (feet above sea level)	Stream length (miles)	Annual precipitation (inches)	West- or east-facing basin	Percentage of basin above 8,000 feet	Percentage of basin above 10,000 feet
10245900	Pine Creek near Belmont	38.80	116.85	1978–2000	12.2	7,560	720	9,842	5.00	21.9	east	98.4	47.5
10245910	Mosquito Creek near Belmont	38.80	116.70	1978–2000	15.1	7,200	447	9,415	7.85	17.3	west	95.4	24.5
10245925	Stoneberger Creek near Belmont	39.14	116.60	1978–1997	35.6	6,880	204	8,415	12.55	16.9	east	73.0	.2
10249300	South Twin River near Round Mountain	38.88	117.24	1965–2000	20.0	6,400	604	8,985	8.10	19.3	east	84.5	12.0
10325500	Reese River near Ione	38.85	117.47	1951–1980	53.0	7,100	180	8,768	13.45	17.2	west	80.6	10.8
—	East Stewart Creek near Ione	38.89	117.36	1987–1992	.36	9,455	1,590	10,170	.85	25.2	west	100	66.7

Historical monthly streamflows could be grossly estimated as follows: (1) use the regression equations in this report to build a streamflow-duration curve for the ungaged site; (2) for each month, determine the percent exceedence for observed streamflow at the nearby gaged index site; and (3) from the streamflow-duration curve for the ungaged site, select the streamflow data corresponding to the same percentile as that experienced at the gaged site for the month of interest.

Basin characteristics at each of the six streamflow gaging-station sites were extracted from USGS topographic maps. Total drainage area was determined by delineating and planimetering basin boundaries on 1:24,000-scale topographic maps. Mean annual precipitation was the basin average precipitation as determined from digital maps (G.H. Taylor, Oregon Climate Service, Oregon State University, written commun., May 1997) using geographic information system (GIS) methods. In a similar manner, mean basin altitude was determined by GIS methods using elevation data from a 1-degree digital elevation model (U.S. Geological Survey, 1995), digitally overlaying a transparent grid on the basin outline, determining the value at the grid intersections, and then averaging the readings. These methods of determining mean annual precipitation and mean basin altitude are different than those used in Hess and Bohman (1996), who used paper topographic maps and manual methods. The stream length was determined by measuring the distance in miles along the main channel from the gaging station to the basin divide. The gage altitude was determined from a topographic map. The channel slope was measured between points, which are 10 percent and 85 percent of the main stream length upstream from the gaging station. A qualitative variable indicating whether a drainage basin is on the east- or west-facing slope of a mountain range also was included in the analyses to determine if a rain-shadow effect was discernible. The basin physical and climatic characteristics for the East Stewart Creek site were used from the previous study.

Drainage basin physical and climatic characteristics associated with each streamflow gaging station used in the regression analysis are listed in table 4. More accurate determinations of basin physical and climatic characteristics could have been determined with greater accuracy using other GIS databases. Their use was beyond the scope of this study.

Monthly streamflow data and basin physical and climatic characteristics at the six gaged sites in the study area were transformed to logarithms and used in a multiple-regression analysis to derive estimating equations of the form:

$$\log Q_{xx} = \log a + b \log A + c \log B$$

Commonly expressed as:

$$Q_{xx} = a A^b B^c$$

where:

Q_{xx} is the monthly mean streamflow with an exceedence probability of xx, in percent;

A and B are basin physical and climatic characteristics; and

a, b, and c are regression coefficients.

Monthly mean streamflows for each exceedence level were related to the basin physical and climatic characteristics using a stepwise regression procedure (SAS Institute, 1995, p. 440). This procedure adds independent variables to the equation, one at a time, until all statistically significant variables have been included.

The results of the regression analyses indicate that total drainage area and percent of drainage area above a 10,000 ft altitude are the most significant variables for estimating monthly streamflow-duration characteristics for ungaged streams in central Nevada. The procedure also provided statistical measures of the reliability of the derived equations such as the coefficient of determination from regression (R^2) and the standard error of estimate (SEE). The equations and statistical results are listed in table 5 for the monthly mean streamflows (for all months) of various exceedence levels and in table 6 for the monthly mean streamflows of various exceedence levels and for the monthly mean streamflow (for specific months).

In a study by Parrett and Cartier (1990) in western Montana, R^2 and SEE for the equations representing specific months, ranged from 0.57 to 0.87 and from 43 to 107 percent, respectively. Averages not available in Parrett and Cartier. In the study area, Hess and Bohman (1996) reported that for all months the R^2 for equations ranged from 0.73 to 0.92 (average 0.85) and the SEE ranged from 51 to 96 percent (average 69 percent); and for specific months the R^2 for equations ranged from 0.33 to 0.97 (average 0.83) and the SEE ranged from 31 to 168 percent (average 74 percent).

Table 5. Equations derived from basin-characteristics method for estimating monthly mean streamflow-duration characteristics for all months at ungaged sites in central Nevada

[Q_{xx}, monthly streamflow exceeded xx percent of the time during any month, in cubic feet per second; A, drainage area, in square miles; E10, percentage of basin at altitudes greater than 10,000 feet; R^2, coefficient of determination from regression analysis; SEE, standard error of estimate]

Regression equation used to estimate monthly streamflow-duration characteristic			R^2	SEE (percent)
Q_1	=	$1.48\ A^{0.913}\ E10^{0.279}$	0.90	66
Q_5	=	$0.550\ A^{0.872}\ E10^{0.374}$	.92	54
Q_{10}	=	$0.317\ A^{0.833}\ E10^{0.414}$	.86	73
Q_{25}	=	$0.170\ A^{0.744}\ E10^{0.349}$	.85	65
Q_{50}	=	$0.074\ A^{0.708}\ E10^{0.385}$	.84	65
Q_{75}	=	$0.038\ A^{0.743}\ E10^{0.436}$	.84	70
Q_{90}	=	$0.027\ A^{0.746}\ E10^{0.429}$	.82	75
Q_{95}	=	$0.023\ A^{0.732}\ E10^{0.433}$	.81	78
Q_{99}	=	$0.018\ A^{0.686}\ E10^{0.427}$	.73	99

In this study, the R^2 and the SEE for the relations are comparable to those ranges. For the regression equations that include all months, the R^2 ranged from 0.73 to 0.92 (average 0.84), and the SEE of the relations ranged from 54 to 99 percent (average 72 percent; table 5). For the specific monthly relations, the R^2 ranged from 0.10 to 0.94 (average 0.72), and the SEE ranged from 36 to 237 percent (average 78 percent; table 6). The accuracy of both types of regression equations developed in this study generally is comparable to those in the previous study by Hess and Bohman (1996). This study had a slight increase in SEE probably because of a wetter period of record (1995–2000) used and a wider range in streamflow values. This range in streamflow values would tend to cause a wider variation in the statistical computations. This example shows that additional data collection does not necessarily ensure a more reliable regression relation, though it may lessen the need for extrapolation and therefore be more robust.

Using the concurrent-measurement method, measured streamflow at four partial-record sites were correlated with concurrent streamflow at nearby gaged sites with continuous records. The relation between the streamflow at the gaged and partial-record sites can then be used to extend the desired long-term streamflow characteristic at the gaged site to the partial-record site. This method was used to estimate monthly streamflows in Montana in Parrett and Cartier (1990). According to Searcy (1959, p. 17) and Riggs (1972, p. 15), the concurrent-measurement method generally provides more reliable estimates of low-streamflow characteristics than other methods in which streamflow measurements are not used.

The concurrent-measurement method using measurements for the period of April to October was applied at selected partial-record sites. Because the 19 monthly measurements were collected from April to October (an average of less than 3 measurements for each month), data are too few to develop a monthly relation for each streamflow-duration characteristic. Because the 19 monthly measurements were collected at partial-record sites, the data are not continuous and, therefore, monthly streamflow-duration relations can not be developed. However, relations for all months combined were developed and are listed in table 5.

To determine this relation, the 19 measurements at each partial-record site were paired with concurrent daily mean streamflow obtained from a similar, nearby continuous-record site. A correlation matrix was used to determine the strength of individual relations between the six continuous-record and four partial-record sites. The correlation matrix indicated which of the six continuous-record sites were statistically the best indicator, or index station, for streamflow at the four partial-record sites. Measurements at the index station were then paired with concurrent measurements made at the partial-record site. Using simple linear-regression techniques, a straight line was fitted through the data points. Parrett and Cartier (1990) used a more elaborate curve-fitting technique at 20 partial-record sites using 12 monthly streamflow measurements. However, for this central Nevada study, only simple linear-regression techniques were used because of the limited amount of data from four sites.

For each partial-record site, the accuracy of the regression relation was examined by comparing observed streamflow to the streamflow determined from the linear regression for the four pairs as listed in table 7. As in the first method, the R^2 was determined for each relation. These values ranged from 0.39 to 0.89 (average 0.72). The SEE was determined by comparing each of the observations for the four sites. The SEE

Table 6. Equations derived from basin-characteristics method for estimating monthly streamflow-duration characteristics for individual months at ungaged sites in central Nevada

[Q_{xx}, monthly mean discharge exceeded xx percent of the time during the specified month, in cubic feet per second; Q_{mean}, mean monthly discharge, in cubic feet per second; A, drainage area, in square miles; E10, percentage of basin at altitudes greater than 10,000 feet; R^2, coefficient of determination from regression]

Month	Regression equation for indicated streamflow characteristic	R^2	Standard error of estimate (percent)
Oct.	$Q_5 = 0.18\ A^{0.75}\ E10^{0.24}$	0.82	55
	$Q_{25} = 0.10\ A^{0.72}\ E10^{0.36}$	.85	46
	$Q_{50} = 0.06\ A^{0.67}\ E10^{0.42}$	.74	61
	$Q_{75} = 0.05\ A^{0.63}\ E10^{0.46}$	.71	65
	$Q_{95} = 0.04\ A^{0.55}\ E10^{0.48}$	.51	90
	$Q_{mean} = 0.13\ A^{0.56}\ E10^{0.14}$	.35	108
Nov.	$Q_5 = 0.19\ A^{0.73}\ E10^{0.20}$	.81	56
	$Q_{25} = 0.11\ A^{0.71}\ E10^{0.31}$	.79	55
	$Q_{50} = 0.06\ A^{0.69}\ E10^{0.41}$	.73	65
	$Q_{75} = 0.04\ A^{0.66}\ E10^{0.44}$	.70	68
	$Q_{95} = 0.03\ A^{0.62}\ E10^{0.50}$	.74	62
	$Q_{mean} = 0.09\ A^{0.67}\ E10^{0.31}$	.74	59
Dec.	$Q_5 = 0.19\ A^{0.69}\ E10^{0.15}$	.81	54
	$Q_{25} = 0.09\ A^{0.70}\ E10^{0.29}$	.76	61
	$Q_{50} = 0.05\ A^{0.70}\ E10^{0.42}$	.72	67
	$Q_{75} = 0.04\ A^{0.69}\ E10^{0.40}$	.66	75
	$Q_{95} = 0.03\ A^{0.60}\ E10^{0.41}$	.43	105
	$Q_{mean} = 0.08\ A^{0.67}\ E10^{0.29}$	.71	65
Jan.	$Q_5 = 0.14\ A^{0.75}\ E10^{0.18}$	.74	74
	$Q_{25} = 0.09\ A^{0.73}\ E10^{0.26}$	.79	58
	$Q_{50} = 0.04\ A^{0.75}\ E10^{0.41}$	.72	72
	$Q_{75} = 0.03\ A^{0.75}\ E10^{0.39}$	.66	83
	$Q_{95} = 0.03\ A^{0.65}\ E10^{0.38}$	.54	91
	$Q_{mean} = 0.06\ A^{0.73}\ E10^{0.30}$	.73	68
Feb.	$Q_5 = 0.11\ A^{0.85}\ E10^{0.19}$	.75	82
	$Q_{25} = 0.07\ A^{0.80}\ E10^{0.25}$	.81	61
	$Q_{50} = 0.04\ A^{0.85}\ E10^{0.37}$	.76	76
	$Q_{75} = 0.03\ A^{0.83}\ E10^{0.40}$	.70	88
	$Q_{95} = 0.02\ A^{0.80}\ E10^{0.38}$	.67	89
	$Q_{mean} = 0.05\ A^{0.83}\ E10^{0.30}$	.76	74
Mar.	$Q_5 = 0.09\ A^{1.03}\ E10^{0.26}$	.69	128
	$Q_{25} = 0.06\ A^{1.00}\ E10^{0.30}$	.76	97
	$Q_{50} = 0.03\ A^{0.98}\ E10^{0.44}$	.74	95
	$Q_{75} = 0.02\ A^{0.93}\ E10^{0.46}$	.75	88
	$Q_{95} = 0.02\ A^{0.88}\ E10^{0.45}$	.65	106
	$Q_{mean} = 0.05\ A^{0.93}\ E10^{0.34}$	.72	97
April	$Q_5 = 0.17\ A^{1.13}\ E10^{0.30}$	0.75	121
	$Q_{25} = 0.12\ A^{0.97}\ E10^{0.36}$	.66	123
	$Q_{50} = 0.07\ A^{0.97}\ E10^{0.40}$	.72	100
	$Q_{75} = 0.03\ A^{0.98}\ E10^{0.59}$	.75	96
	$Q_{95} = 0.02\ A^{0.97}\ E10^{0.55}$	.74	95
	$Q_{mean} = 0.08\ A^{1.05}\ E10^{0.32}$	.81	77
May	$Q_5 = 1.39\ A^{0.99}\ E10^{0.18}$	.89	59
	$Q_{25} = 1.43\ A^{0.86}\ E10^{0.10}$	.87	59
	$Q_{50} = 0.18\ A^{0.95}\ E10^{0.51}$	.82	72
	$Q_{75} = 0.03\ A^{1.02}\ E10^{0.83}$	.82	88
	$Q_{95} = 0.03\ A^{0.94}\ E10^{0.72}$	.77	91
	$Q_{mean} = 0.19\ A^{1.06}\ E10^{0.41}$	.81	82
June	$Q_5 = 2.65\ A^{0.89}\ E10^{0.17}$	.94	36
	$Q_{25} = 0.86\ A^{0.74}\ E10^{0.34}$	.84	50
	$Q_{50} = 0.28\ A^{0.77}\ E10^{0.52}$	.71	79
	$Q_{75} = 0.13\ A^{0.69}\ E10^{0.59}$	.77	66
	$Q_{95} = 0.06\ A^{0.63}\ E10^{0.77}$	.88	53
	$Q_{mean} = 0.34\ A^{0.90}\ E10^{0.42}$	.87	55
July	$Q_5 = 0.11\ A^{0.80}\ E10^{0.22}$	.69	88
	$Q_{25} = 0.32\ A^{0.69}\ E10^{0.35}$	.87	40
	$Q_{50} = 0.13\ A^{0.71}\ E10^{0.44}$	.82	52
	$Q_{75} = 0.11\ A^{0.58}\ E10^{0.43}$	.69	61
	$Q_{95} = 0.07\ A^{0.44}\ E10^{0.51}$	.73	55
	$Q_{mean} = 0.24\ A^{0.70}\ E10^{0.29}$	.81	50
Aug.	$Q_5 = 0.41\ A^{0.76}\ E10^{0.20}$	.85	52
	$Q_{25} = 0.16\ A^{0.68}\ E10^{0.35}$	.87	39
	$Q_{50} = 0.12\ A^{0.62}\ E10^{0.33}$	.72	58
	$Q_{75} = 0.07\ A^{0.51}\ E10^{0.39}$	.61	64
	$Q_{95} = 0.11\ A^{0.22}\ E10^{0.29}$	.10	101
	$Q_{mean} = 0.12\ A^{0.40}\ E10^{0.11}$	.21	171
Sept.	$Q_5 = 0.27\ A^{0.73}\ E10^{0.20}$	.86	237
	$Q_{25} = 0.12\ A^{0.67}\ E10^{0.33}$	.80	50
	$Q_{50} = 0.07\ A^{0.60}\ E10^{0.39}$	.66	66
	$Q_{75} = 0.05\ A^{0.56}\ E10^{0.45}$	.60	74
	$Q_{95} = 0.05\ A^{0.43}\ E10^{0.44}$	.38	96
	$Q_{mean} = 0.13\ A^{0.60}\ E10^{0.16}$	.58	72

Table 7. Equations derived from concurrent-measurement method for estimating monthly streamflow for all months at partial-record sites in central Nevada using streamflow at nearby gaging stations

[Q_{xx}, streamflow at site, in cubic feet per second; R^2, coefficient of determination from regression analysis. Abbreviation: SEE, standard error of estimate]

Regression equation used to estimate monthly streamflow-duration characteristic			R^2	SEE (percent)
$Q_{Andrews}$	=	$0.141\ Q_{Pine} + 0.01$	0.89	76
Q_{Barley}	=	$1.94\ Q_{Mosquito} + 0.1$	.76	1,023
$Q_{Corcoran}$	=	$0.020\ Q_{Mosquito} + 0.3$	.39	14
Q_{Morgan}	=	$0.319\ Q_{Mosquito} + 0.01$	.86	37
$Q_{Andrews}$	=	$0.141\ Q_{Pine} + 0.01$	.89	76

varied from 14 percent (Corcoran Creek), 37 percent (Morgan Creek), 76 percent (Andrews Creek) to 1,023 percent (Barley Creek). Barley Creek has a wider variation in streamflows (0 to 89 ft^3/s) than the other concurrent sites which could be the reason for the higher SEE. Using the other three sites, the average SEE is 42 percent. As a comparison, in the Parrett and Cartier (1990) study, the standard error ranged from 19 to 92 percent using this technique.

Comparison of the average SEE for the concurrent-measurement method (42 percent) with the average SEE for the basin-characteristics method (72 percent) indicates that the concurrent-measurement method typically is more reliable than the other method for estimating monthly streamflows for any month of the year. A similar comparison of R^2 (0.72 and 0.84, respectively) indicates the same conclusion.

RELIABILITY AND LIMITATIONS OF ESTIMATING METHODS

The statistical reliability of many of the equations is poor because only six observations (continuous-record sites) were available for the analyses. These limited observations did not allow proper definition of the true relation of each independent variable to the dependent variable in most equations. More observations generally would improve the reliability of regression equations.

The regression equations determined in the basin characteristics method may not be applicable beyond the range of values (table 4) used to derive the equations. Extrapolation beyond the values listed in tables 5 and 6 may yield estimates with greater errors than those indicated.

The equations presented in this report are valid only for: (1) streams in the study area; (2) streams on the mountain block areas; (3) perennial streams; and (4) streams with insignificant diversions and regulation upstream of the site of interest. The equations are *not* valid for: (1) streams in the valleys or on alluvial fans; (2) streams in areas with fractured consolidated bedrock that tend to lose surface water streamflow to ground-water; and (3) estimating historical streamflows resulting from summertime convective storms which may have been caused by localized runoff in isolated parts of the study area.

Even though the concurrent-measurement method typically is more accurate than the basin-characteristics method, the concurrent-measurement method requires additional streamflow data collection at partial-record sites for several years. As applied to this study, the concurrent-measurement method cannot be used for estimating monthly streamflow-duration characteristics for individual months due to an inadequate number of monthly streamflow measurements.

Snowmelt is the primary source of water for streamflow in central Nevada during certain times of the year. Snowmelt induced streamflows may vary diurnally by as much as 100 percent. Streamflow measurements were made at the continuous- and partial-record sites during the same day, but never at the same time during the day. Diurnal variations, thus, may introduce an error into concurrent-measurement method calculations during periods of snowmelt.

APPLICATIONS

General procedures for making estimates of monthly streamflows using methods described herein are illustrated in the following examples:

Example 1: An estimate of the monthly streamflow rate exceeded 50 percent of the time (Q_{50}) for July is required for an ungaged site in the study area. The following basin characteristics were measured from a topographic map:

$$\text{Drainage Area (A)} = 10\ mi^2 = A$$

$$\text{Percentage of basin above 10,000 ft elevation (E10)} = 25.0 = B$$

Monthly streamflow-duration characteristics for 50 percent exceedence (Q_{50}; table 5) is calculated as follows:

$$Q_{50} = 0.074\ A^{0.708}\ E10^{0.385}$$
$$Q_{50} = 0.074\ (10)^{0.708}\ (25.0)^{0.385}$$
$$Q_{50} = 1.30\ ft^3/s$$

Values of Q_1 to Q_{99} are calculated from the equations listed in table 5. Streamflow-duration data from the index station, Mosquito Creek near Belmont, are plotted on arithmetic probability paper (fig. 2) with the values of Q_1 to Q_{99}. The monthly mean streamflow of Mosquito Creek for July is 3.28 ft^3/s (table 1). Examination of the streamflow-duration curve for Mosquito Creek shows that the 3.28 ft^3/s value is exceeded 14 percent of the time. Returning to the streamflow-duration curve for the ungaged site determined from table 5, the streamflow associated with the percentage of time exceeded is 14 percent is 6.0 ft^3/s. Thus, the monthly mean streamflow for July at the ungaged site is 6.0 ft^3/s.

Example 2: Estimates of the monthly mean streamflow for July is required for an ungaged site in the study area. The following basin characteristics were measured from a topographic map:

Drainage Area (A) = 10 mi^2 = A

Percentage of basin above 10,000 ft elevation (E10) = 25.0 = B

Monthly mean streamflow is determined by calculating Q_{mean} (table 6) as follows:

$$Q_{mean} = 0.24A^{0.70}\ E10^{0.29}$$
$$Q_{mean} = 0.24(10)^{0.70}\ (25.0)^{0.29}$$
$$Q_{mean} = 3.1\ ft^3/s$$

Thus, the monthly mean streamflow for July at the ungaged site is 3.1 ft^3/s.

Example 3: An estimate of the streamflow at Andrews Creek for the monthly Q_{95} is needed. By use of the relation between Pine Creek (continuous-record index station) and Andrews Creek (partial-record site with concurrent measurements) applicable equations from table 7, the monthly streamflow-duration characteristic for Q_{95} Pine Creek from table 3 is 1.02 ft^3/s. For example, $Q_{95\ Andrews}$ is calculated as follows:

$$Q_{95\ Andrews} = 0.141\ (Q_{95\ Pine\ Creek}) + 0.01$$
$$Q_{95\ Andrews} = 0.141\ (1.02) + 0.01$$
$$Q_{95\ Andrews} = 0.15\ ft^3/s$$

Thus, the monthly streamflow for Andrews Creek Q_{95} is 0.15 ft^3/s.

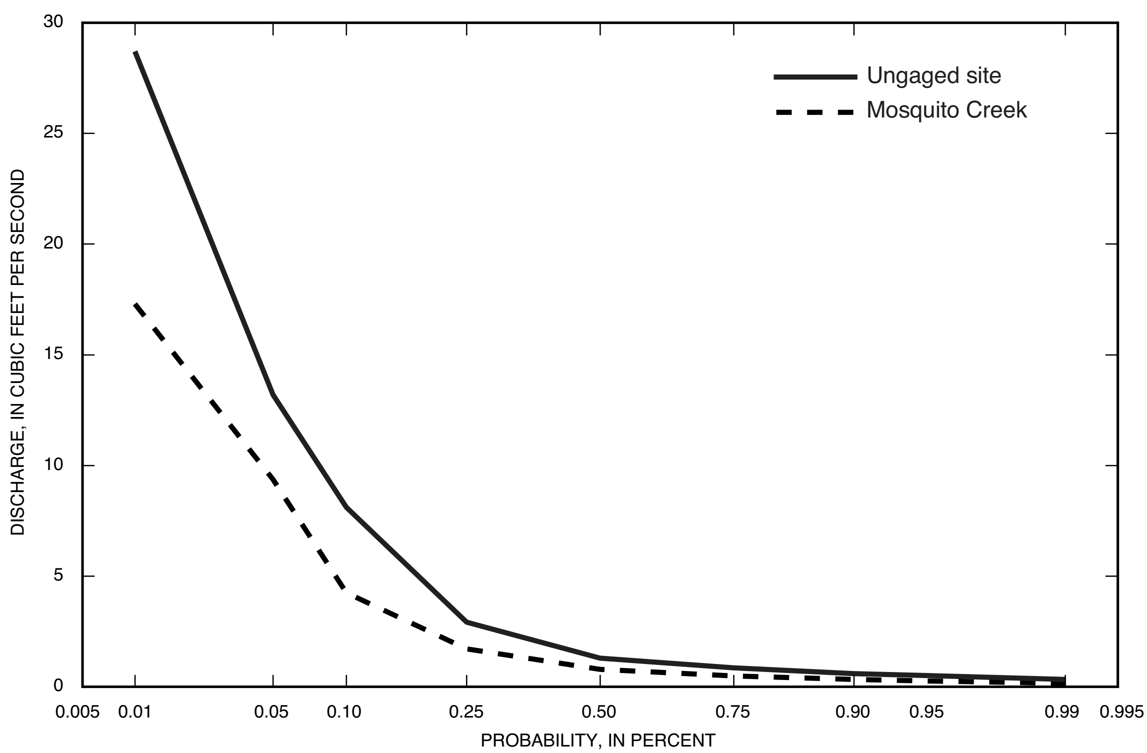

Figure 2. Probability of streamflow-duration data from the index station, Mosquito Creek near Belmont, used in example 1 application.

SUMMARY

Two methods, the basin-characteristic method and the concurrent-measurement method, were developed to update estimating techniques for selected streamflow characteristics at ungaged and partial-record sites in central Nevada. Gaged streamflow data were available from six sites within the study area and streamflow measurements were available for 4 years at partial-record sites with concurrent measurements.

In the first method, basin-characteristics method, streamflow data at gaged sites were related to basin physical and climatic characteristics by regression techniques. Total drainage area, percent of drainage area above 8,000 and 10,000 ft, channel slope, stream length, gage altitude, mean basin altitude, and mean annual precipitation were determined for each basin. Monthly streamflow data for selected percent exceedence levels were used in regression analyses with basin physical and climatic variables to determine relations for ungaged basins. Analyses indicate that the total drainage area and percent of drainage area at altitudes above 10,000 ft are the most significant variables. For equations in which all months of the year were combined, the R^2 averaged 0.84 and the SEE of the relations averaged 72 percent. For equations representing individual months of the year, the R^2 averaged 0.72 and the SEE of the relations averaged 78 percent. The statistics for both the combined and individual monthly regression equations indicate that the updated relations are slightly less accurate than those developed in a previous study. This difference is probably the result of additional streamflow data collected during wetter periods (1995–2000) used in the current study, which has a wider range in streamflow values.

In the second method, concurrent-measurement method, streamflow measurements at partial-record sites were correlated with concurrent streamflows at nearby continuous-record sites by the use of linear-regression techniques. Statistical measures typically were more reliable than for the first method. However, the concurrent-measurement method requires additional streamflow data collection at partial-record sites to develop relations for individual months.

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